CANADA CENTRE FOR INLAND WATERS

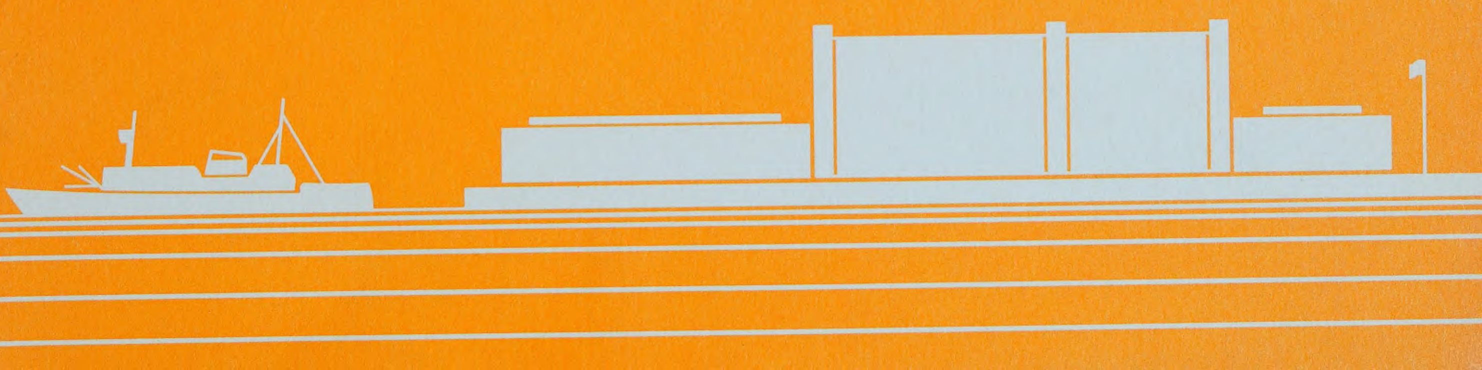
Papers

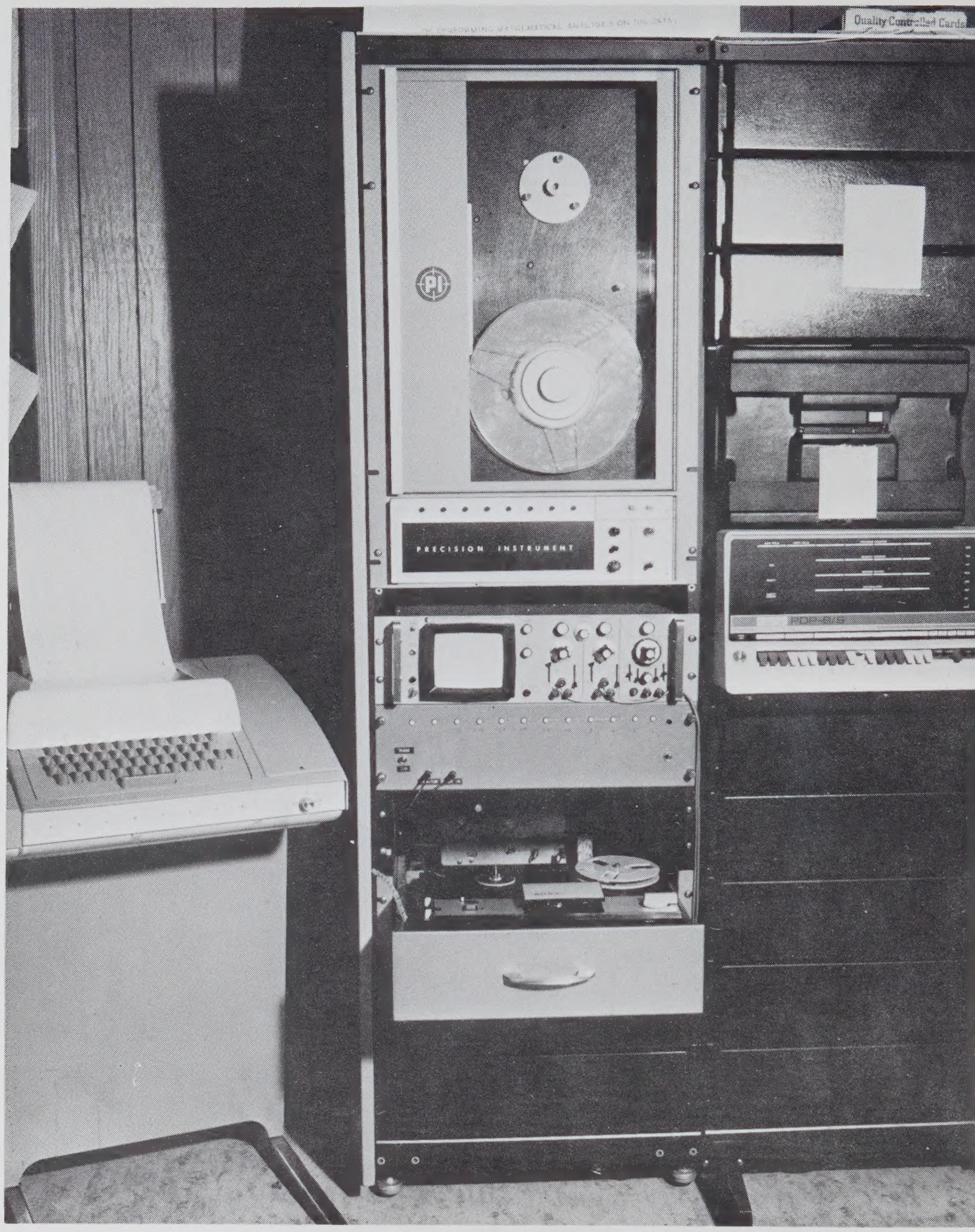
No. 1

A Digital Translation System

K. R. Peal

CCIW PAPER No. 1 1969





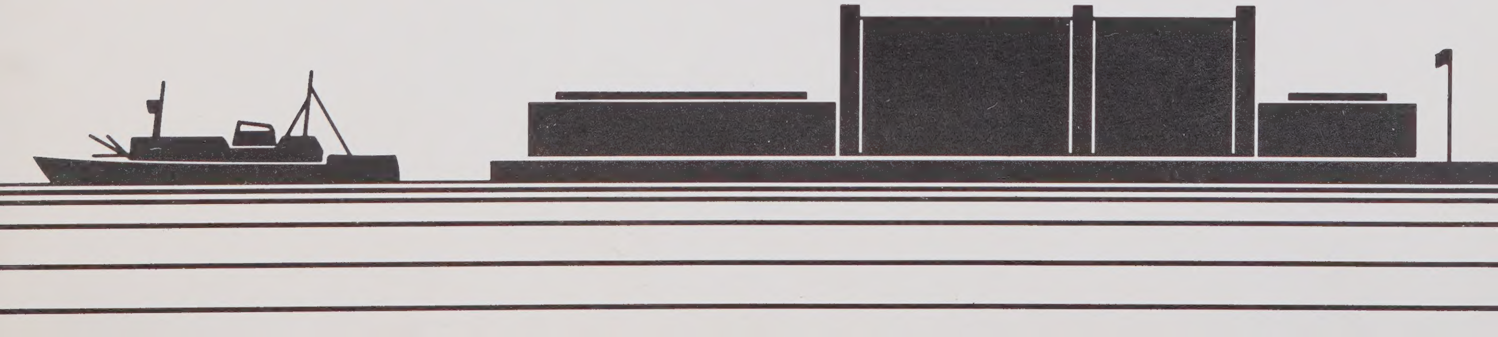
Frontispiece - CCIW Data Translator

CANADA CENTRE FOR INLAND WATERS

A Digital Translation System

K. R. Peal

Distribution restricted to Canadian Universities and Governments



Contents

Illustrations

Abstract

A computer-based system has been designed and constructed for translating pure binary data (recorded in the field on 1/4" magnetic tape) into computer-compatible binary coded decimal (BCD) data (on 1/2" 7-track magnetic tape). The system performs error checking and flags the suspect data in its translated form. Two forms of visual monitoring during translation are also provided.

Previous to each translation, information identifying the tape being translated is written onto the 1/2" tape as a header record. A summary is printed out immediately following each translation which lists the total number of data words and the total number of various error types found in the input data.

The translation time for 600 feet of 1/4" tape is 30 minutes. A semi-skilled operator controls the system at a teletype keyboard using single-character commands.

A Digital Translation System

K. R. Peal, P. Eng.

INTRODUCTION

In the course of the field program conducted by C.C.I.W., many meteorological and lake parameters are recorded. These include wind velocities, air temperatures, humidity, solar radiation, water level, water current velocities and water temperatures.

At present, a large percentage of these parameters are recorded *in situ* using recording packages manufactured by the Plessey Co., Marine Sciences Division. Over 50 such packages are used in a program which covers both Lakes Ontario and Erie. Each package reads and records each parameter (normally 6 or 8 parameters for each unit) every 10 minutes. Thus, during each field season, which lasts several months, a large volume of data is collected.

In order to make efficient and timely use of these data, it is desirable to use digital computing facilities. In this way, it is possible to change the raw data from numbers to physical measurements and to examine them on a large scale to perform correlation studies and lake modelling, for example. Thus, it is necessary to change the recorded data into a form which can be read conveniently by large-scale computers. This process is referred to as *data translation* and is the purpose of the system described in this report.

The scope of this report is the phase I version of the translator. Appendix A explains the general scope of the system and the plans for expansion. "Phase I" means that data from Plessey instruments, which record 4, 6,or 8 parameters, can be translated. These instruments are referred to as 4, 6, or 8-channel devices respectively.

The parameters of interest to each instrument are recorded in the instrument using a built-in, single track, magnetic tape recorder (see Figure 1). The value of each parameter is converted to a 10-bit binary

Figure 1. Plessey Recording Instrument with protective case removed.

number and recorded serially on the 1/4" tape. Each such number is referred to as a data word. At each 10-minute sample point, all the parameters are converted in this way and recorded in series on the tape. Then the tape recorder is stopped until the next sample is taken. Thus, the completed tape contains a continuous series of data words.

In addition to the recorded data words, a single bit is recorded once during each sample point. It is referred to as the reference bit. It is recorded in the space between two successive data words. In the case of a 6-channel device, it is always located between channels 5 and 6 and thus can be used to associate the channel numbers with the appropriate data words on the tape (see Figure 2). A similar scheme is used for 4 and 8-channel devices.

The function of the translator is to read the data from the 1/4" tapes, convert this data into computer-compatible form, and write the converted data onto a medium which can be read by large-scale computer installations. It also keeps track of the channel number and checks for various errors in the recorded data. The location of each error is noted in the translated output and a data and error summary is typed after each translation.

DESCRIPTION

In order to provide flexibility and to make the system generally useful, it was decided to build the translator around a small general-purpose computer. Not only can a computer do the basic numerical conversion and control the system operation, but it can be programmed to react to certain special conditions and accumulate information about the progress of the translation.

The computer chosen was a basic PDP-8/S, made by Digital Equipment Corporation. This is a small, inexpensive machine which is relatively slow (add time 36 microseconds) but designed for data processing where ease of interfacing to peripheral equipment is important. It has a memory of 4096 12-bit words with a cycle time of 8 microseconds. It comes interfaced to a teletype (ASR 33) which is used for communication (via the keyboard) and programming (via the paper-tape reader and punch).

The complete system is shown in the frontispiece and in Figure 3. To perform a translation, the 1/4" data tape, returned from the field, is placed on the audio tape recorder and the system is started. The basic data flow path is from the audio tape recorder, through the input interface, into the computer where conversion takes place. After conversion, the flow path is through the output interface, onto the 7-track tape. The tapes thus produced can be read on a large-scale computer where the main data analysis and reduction are performed.

When the translation program is in the computer memory and running, the system is completely controlled by commands from the teletype. Initially, the program requests information from the operator about the type of data (e.g., number of channels). Then the operator can enter indentifying information about the particular tape which is to be translated. When this information is complete and correct, the operator gives a "record" command which causes it to be written as a header record on the output tape.

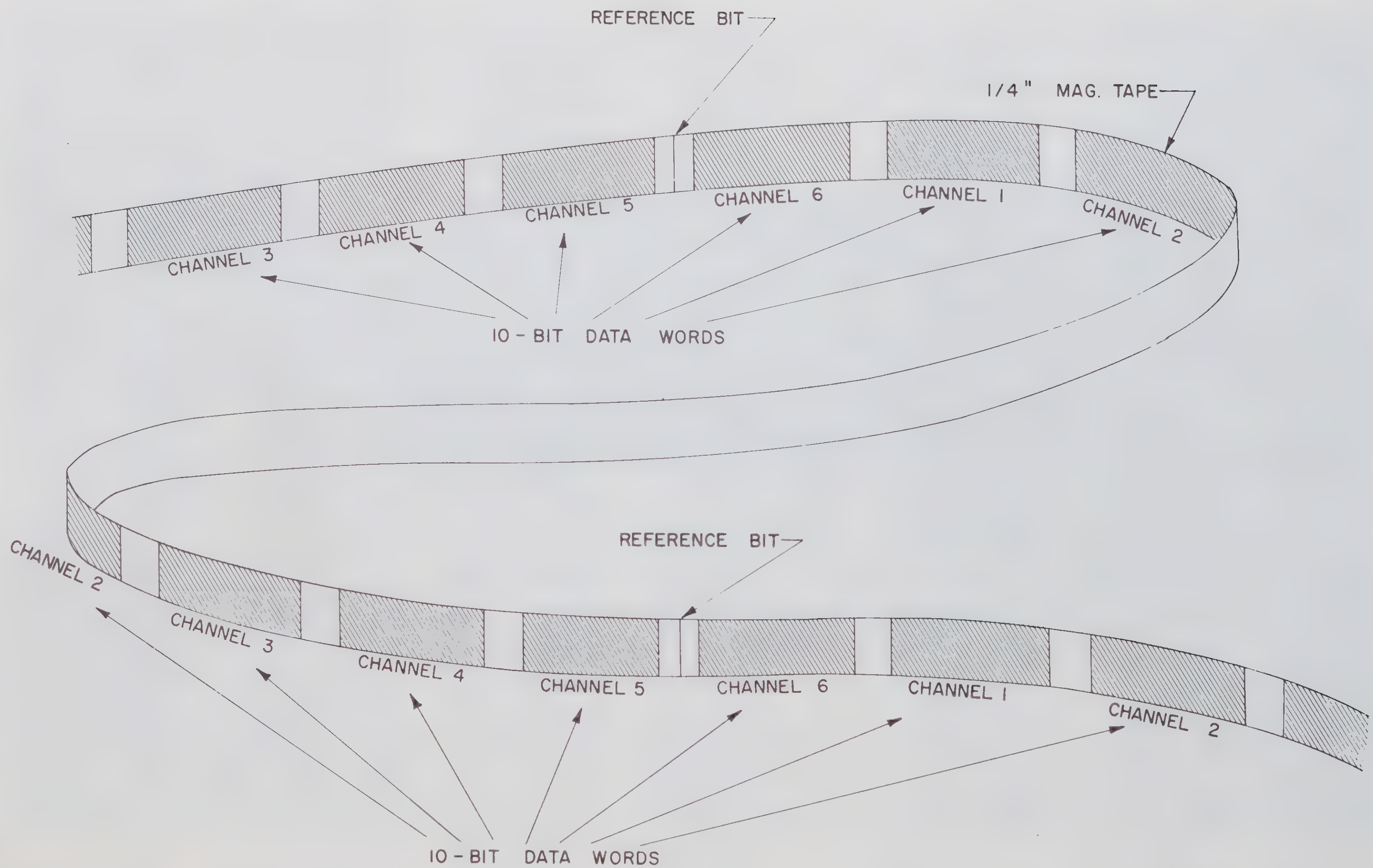


Figure 2. Data Format on 1/4" tape (6 channel).

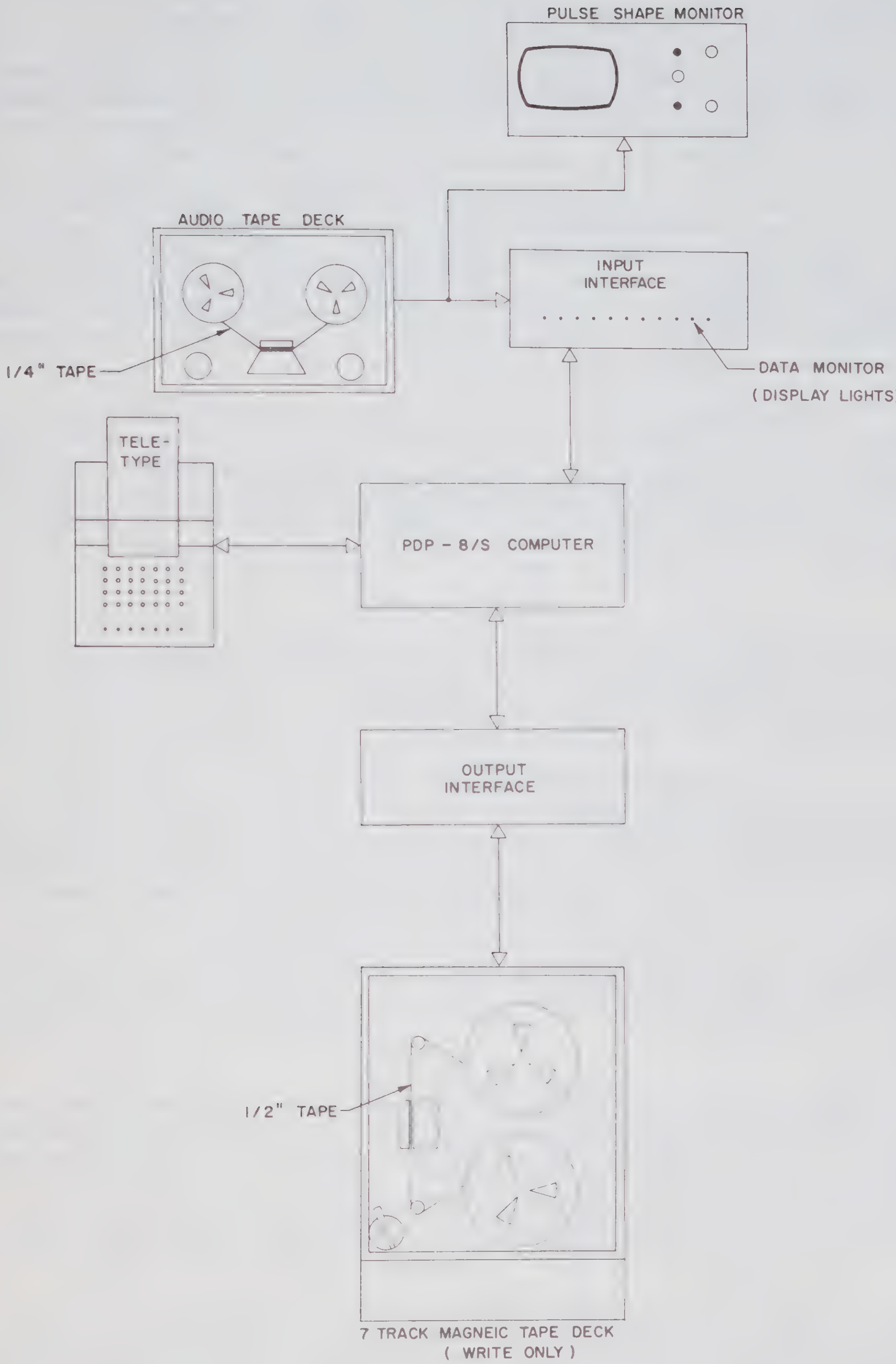


Figure 3. System Block Diagram.

The actual translation is then begun by starting the audio tape recorder on "play". Translation then continues automatically (unless interrupted by the operator) until the end of the data is reached. Details of the program which performs these operations appear in Appendix B.

The pulse shape monitor is an oscilloscope which continuously monitors the output signal from the tape recorder. The operator observes this display and classifies the general shape of this signal into one of several categories. This information is useful in instrument maintenance.

Also during translation, a set of 10 indicator lights on the interface panel displays the binary data from one of the channels on the data tape. The particular channel being displayed can be selected by the operator during translation. This function is performed partly by the interface and partly by the program. It is possible from this display to obtain a rough estimate of the validity of the recorded data. This is very often of interest to the scientists and to the maintenance personnel.

Various other functions are performed by the "input interface". It assembles each data word from the tape and signals the computer when a word is ready to be read in. At the same time, it counts the number of bits in each word and checks for bits which are excessively short. This information is sent to the computer as error bits, along with the data word itself. Finally the interface signals the computer whenever a reference bit is encountered on the data tape. Details of this interface appear in Appendix C.

In the computer, the binary words are stripped of their error bits, converted to binary coded decimal (BCD) and assembled in blocks along with appropriate error bits ready to be written onto the output tape. The locations of the reference bits are also noted in the blocks assembled for output. Other functions of the program are explained in Appendix B.

The output interface controls the operation of the 7-track tape recorder. The computer supplies data and step commands to the interface which then controls the incremental writing of the data onto the tape. The converted data words being written in BCD on the tape consist of four numeric characters, followed by a flag character. Since the binary word length is 10 bits, the BCD words are less than 1024 and thus consist of four numeric characters. The flag character following each word is used to indicate the occurrence of errors and reference bits. The output data are arbitrarily blocked into sets of 480 characters (96 words). After each block of data, an end-of-record gap is written. A complete description of the output interface appears in Appendix D.

When the end of the input data is reached, it is probable that the last block of output data is shorter than 480 characters. When the operator determines that the end of the input data has been reached, he terminates the translation by a command from the keyboard. This causes the final short record to be written onto the output tape followed automatically by an end-of-record gap and then an end-of-file gap. The computer then prints on the teletype a summary of information about the translation just completed.

The teletype output then contains the header information for the translated tape, followed by the data summary. The header normally contains information such as the translation data, as well as complete field information about the data. Thus this teletype output is used as a translation report to be stored with the data tape.

OBSERVATIONS

At the time of writing, the system has been operational for about a month. During that time it has seen extensive service successfully handling data from four categories of pulse shape. As discussed in Appendix B, the system is designed to be indestructible by operator error or unusual input signals. However, one system failure did occur which was apparently caused by a power failure.

Operating and maintenance manuals have been written and a semi-skilled operator was trained to use the system in about one week.

A full scale analysis program (for a CDC-6400 computer) is being modified to accept the output tapes from this system. However, a simple dump program, which transfers the BCD numbers directly from the tapes to a line printer has also proved useful.

The two monitor facilities and the data summary are proving to be very useful in instrument maintenance and reliability studies.

It is anticipated that the various benefits being accrued from the system will justify the cost on the basis of this phase I version alone (system costs are listed in Appendix E).

RECOMMENDATIONS

It is recommended that the system be operated by Data Processing on a routine basis. It is also recommended that the operator keep log books showing the time usage of the PDP-8/S and the function usage of all the 7-track tapes used on the system. The operator should also log observations from the pulse-shape monitor to be reported to Engineering.

It is recommended that Engineering maintain contact with Data Processing and Physical Limnology to determine if any further modifications should be made to the system. These may be necessary because of changing requirements, unusual data errors, or unpredictable system bugs.

It is recommended that for the present, Engineering perform periodic system maintenance as outlined in the maintenance manual. These procedures may be modified and the maintenance turned over to Data Processing when more operational experience is gained.

It is recommended that other agencies be made aware of the capabilities of the system and that system time be made available to them as required to translate their Plessey tapes. Of course, this time will have to be arranged in conjunction with C.C.I.W. requirements for the system.

It is recommended that constructional details of the system be made available to non-commercial concerns upon request.

It is recommended that development of phase II proceed as soon as possible. This will consist of adding the capability of transferring onto 7-track tape, data from punched paper tape and data from magnetic tape recorded in Geodyne A 920 current meters. The reason for the urgency of these two items is that (a) a considerable backlog of punched paper tape from the HP data acquisition system already exists, and (b) twenty-two of the Geodyne current meters are to be in operation during the 1969 field season.

Appendix A

Long Term Philosophy for Translation

The impetus for the creation of this system was the desire to design a single translation facility that could be adapted to accept raw data from various sources. It was hoped that this would obviate the acquisition or construction of many special-purpose translators as new data acquisition systems were introduced at C.C.I.W.

The 1/2" computer-compatible output tape was chosen because it is almost universally used as an input device for large-scale computers. Also it was easy to interface a small computer to a suitable write-only tape recorder for generating these tapes.

Since the system is built around a computer, it is possible to expand the system by adding peripherals and writing suitable additional programs. For example, an analog to digital converter with a multiplexer could collect data from many analog sources simultaneously. A high speed paper-tape reader would enable various formats of punched paper-tape data to be translated. Telemetered data could be received and written onto the 1/2" magnetic tape if suitable receivers were interfaced to the system. Various forms of data on 1/4" magnetic tape can be translated if suitable interfaces between the tape deck and the computer are constructed.

The first phase in implementation of this idea has been the Plessey tape translation system for 4, 6, or 8-channel data. A program change will enable the new 12-channel tapes to be translated. Additional programming will enable paper tapes from the Hewlett Packard DY-2010B data acquisition system to be handled. A new tape deck-to-computer interface plus additional programming will permit translation of the tapes from A 920 Geodyne current meters. The phase II development of the system will consist of the latter two additions.

Appendix B

Program Details

The program to operate the system in its phase I form occupies 1650 locations in core (including messages) plus approximately 1000 locations used as buffer areas. It is written in assembly language for the Macro-8

assembler. Listings and tapes are available from the author. Figure B1 is a flow diagram of the program.

The program is designed so that when it is loaded into core and started, the system is completely controlled from the teletype keyboard. In this way, the computer console can be locked and the system can be operated by personnel who are unfamiliar with computers. The keyboard commands are single-character commands which are echoed in all cases. If an illegal command is given, the computer types a question mark and returns to a teletype waiting loop.

In addition, the program is written so that all unusual conditions cause a diagnostic message to be printed, after which the program returns to the teletype waiting loop. Thus, it is always possible to recover the system operation from the teletype. This may be necessary, for example, when the 7-track tape is incorrectly mounted or when very bad data is encountered on an input tape.

When the program is started, it asks if the tape to be translated is from a 4, 6, or 8-channel device and which channel should be displayed initially. Then the operator may select a level-set option ("L" on Figure B1) which enables the system to read and examine the input data without translating it or writing it onto the 7-track tape.

While the system is in level-set mode, the operator can do a preliminary examination of the data and set the correct signal level from the audio tape deck by observing the pulse shape monitor. Also, in this mode, the system operates the data display monitor. Thus, this mode is useful for cursory examination of experimental or poorly recorded data for which no translation is desired.

When the operator is ready to begin the actual translation, he gives the "begin translation" command ("B" on Figure B1). The system then asks for header information about the tape to be translated. The operator can type information in free format into a buffer in the computer memory. After any necessary corrections or changes have been made, the operator gives a "record" command. This puts the header information onto the tape as the first record.

The system is then automatically initialized and waits for the audio tape deck to be started. When input data is received, the translation begins. The binary numbers are converted to BCD numbers by successively subtracting the binary equivalents of appropriate decimal numbers (1000, 800, 400, 200, 100, 80, 40, 20, 10, 8, 4, 2, 1). The converted words are stored in an output buffer ready to be written onto the output tape. Error bits associated with questionable readings are also placed in the output buffer to indicate which words have potential errors.

When a reference bit is read in from the data tape, it allows the various data words to be assigned their correct channel numbers. This enables the program to control the data display monitor and to check for missing readings. The location of each reference bit is identified in the output buffer.

During the translation, the program keeps running totals of the number of reference bits, the number of four different types of errors and the number of output blocks (i.e., the number of times the output buffer is

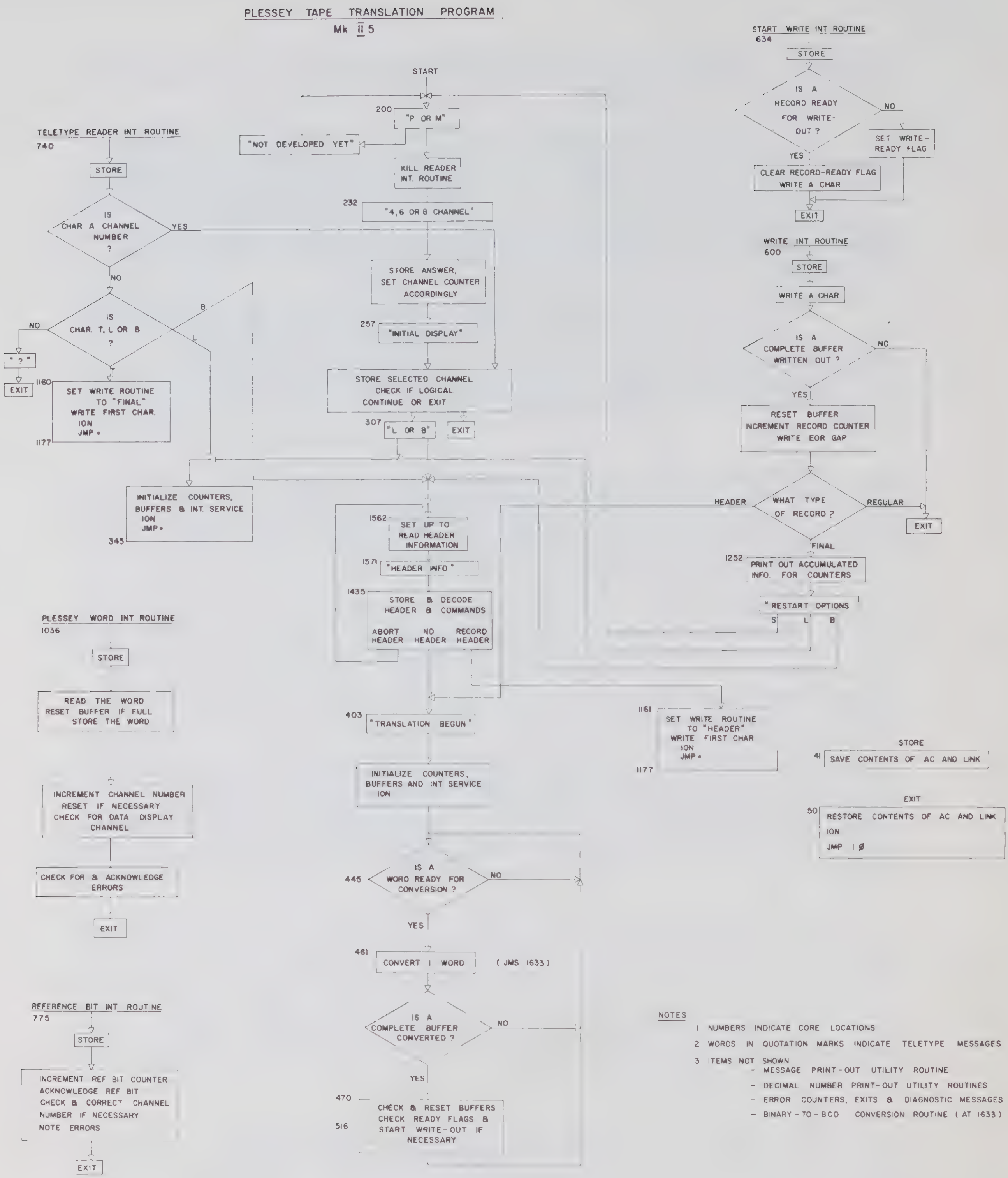


Figure B1. Plessey Tape Translation Program.

filled). At the end of each translation, this information is typed out as a data summary.

During translation, the operator can change the displayed channel, abort the translation or terminate the translation (see "teletype int. routine", Figure B1). Aborting the translation simply returns the system to level-set or header mode, while terminating it produces the typed summary of the translation up to that point. Normally, the translation proceeds to the end of a tape; then, the operator gives a terminate command ("T" on Figure B1).

After the summary is typed out, the system can be restarted (by a teletype command) at various points in the program in order to perform another translation ("restart options", Figure B1). At each restart, the system is initialized so that continuous successive translations can be performed simply by looping repeatedly through the program.

The translation itself is performed by the machine with the program interrupt enabled. This is necessary because the audio tape recorder is unmodified and thus cannot be stopped without losing some data (the density on the tape is about 200 bits per inch). It is thus necessary to read, convert and write the data fast enough so that a fixed buffer size can be used (i.e., the buffer must be emptied by the machine slightly faster than the audio-tape recorder fills it).

The speed of operation is machine limited in two ways. Since the actual binary-to-BCD conversion takes about 4.5 milliseconds and since a considerable amount of bookkeeping and checking is performed, it is necessary to run the audio tape recorder at 3 3/4 inches per second, although it has a 7 1/2 speed. Otherwise, certain pairs of words are merged and data is lost.

Secondly, it is necessary to run the 7-track tape recorder asynchronously at 200 steps per second instead of synchronously at 500. The reason for this is that there are several devices being serviced on the program interrupt, so without a priority interrupt system, a considerable delay can occur before a particular device is serviced. In this case, the delay is sufficient to prohibit synchronous operation of the tape recorder. A software priority interrupt system has been developed but the response time is still not fast enough for reliable synchronous operation. The operation of this tape recorder is explained in more detail in Appendix D.

Appendix C

Input Interface

The operation of the input interface can be represented by the block diagram in Figure C1. The signal from the tape deck is amplified and then each bit is examined to determine if it is a one or a zero. The result is shifted into the device buffer. Also the bit-length is checked and the number of bits is counted.

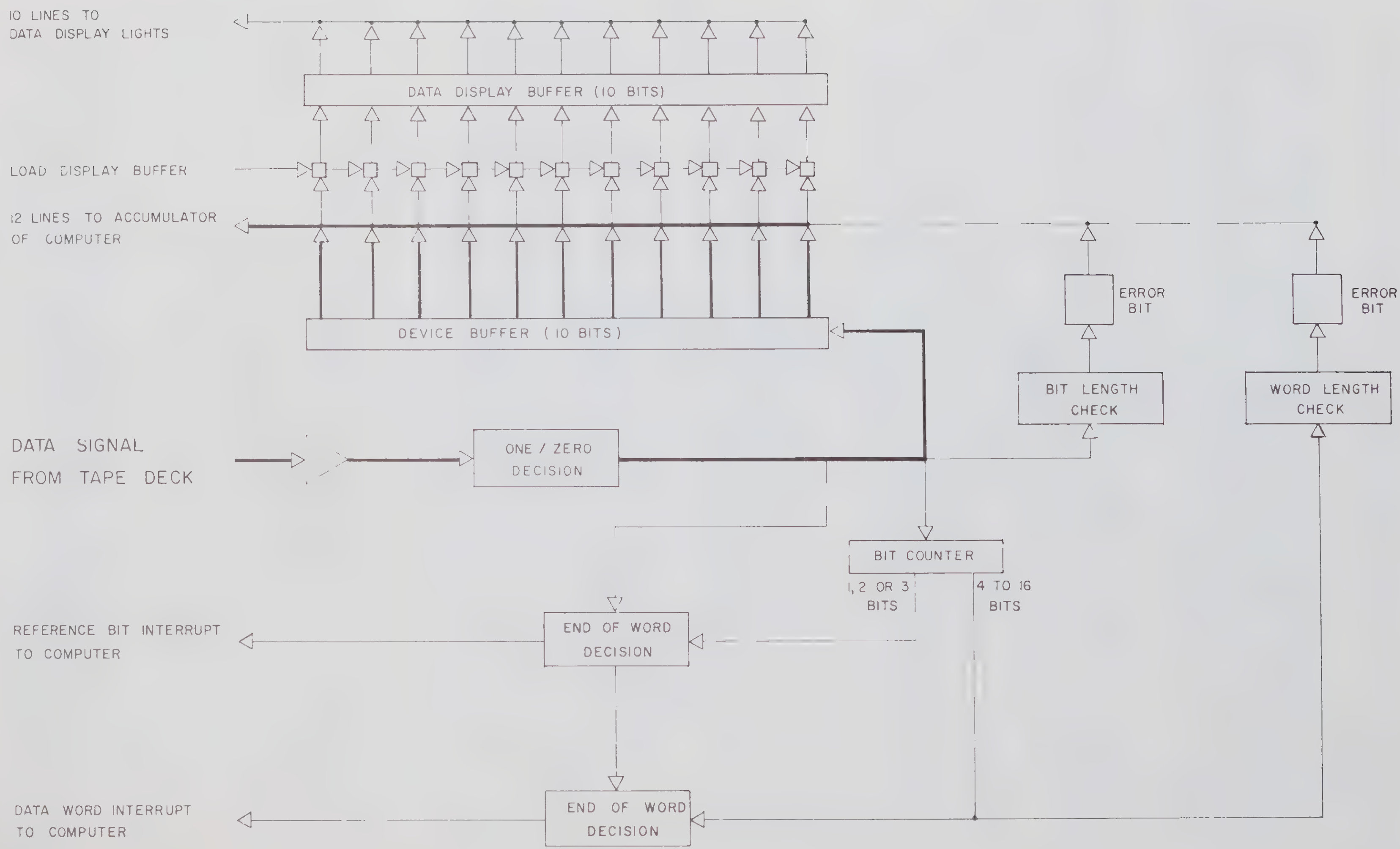


Figure C1. Input Interface Block Diagram.

The space between words on the tape is detected to generate the end-of-word signal. This then sends the appropriate interrupt to the computer, depending on the bit count. The computer reads in the word from the device buffer as a new data word (plus error bits) or else it acknowledges the occurrence of a reference bit.

The "load display buffer" signal reads the contents of the device buffer into the data display buffer. This signal is generated each time that a word from the channel, which is being displayed, is in the device buffer. Thus the data display buffer always holds the most recent data word from the selected channel. This buffer drives the data display lights directly.

Figure C2 shows the complete interface schematic, and Table C1 shows the components and costs. The interface was constructed using Digital Equipment of Canada modules and hardware. The column headed "Part No." lists DEC part numbers for these items.

TABLE C1

Input Interface Components

Part No.	Qty.	Unit Pr. $ U.S.	Price $ U.S.
R107	1	24.00	24.00
R111	1	14.00	14.00
R121	2	17.00	34.00
R123	3	19.00	57.00
R202	14	25.00	350.00
R204	1	28.00	28.00
R302	2	44.00	88.00
R303	1	45.00	45.00
R602	1	22.00	22.00
R603	1	28.00	28.00
W050	2	13.00	26.00
W103	2	52.00	104.00
W501	2	13.00	26.00
W510	1	17.00	17.00
W028 Cables W028	6 6 ft., 2 conn.	29.60	177.60
W028 Cable	1 6 ft., 1 conn.	16.60	16.60
64 Card Rack 1943	1	121.00	121.00
Indicators	10	3.00	30.00
Panel & Brackets	1 set	25.00	25.00
Total Price $ U.S.			1233.20
	+ 10%		123.32
Approximate Total Canadian Price			$1356.52

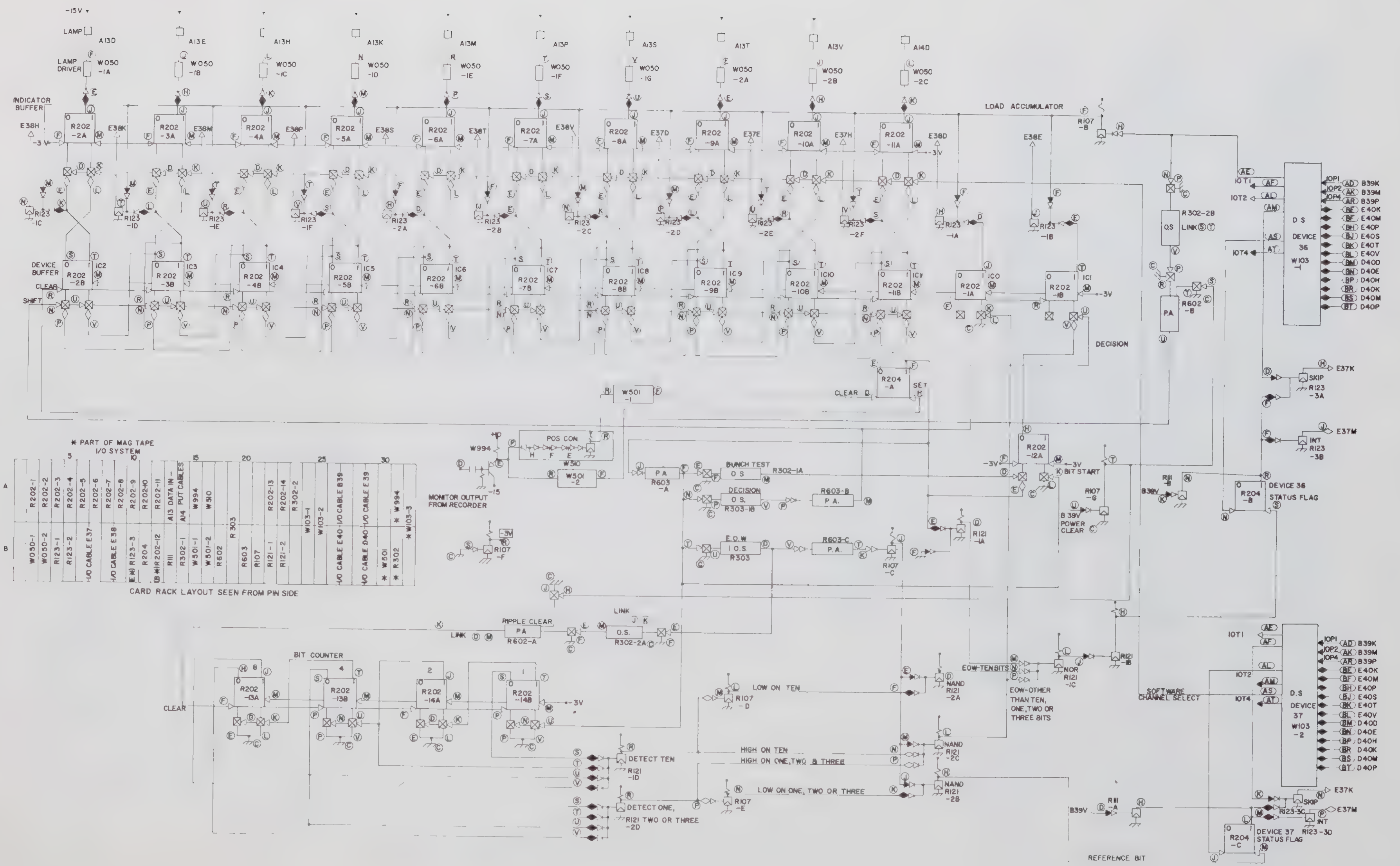


Figure C2. CCIW Data Translator - Sony Tape Recorder Interface

Output Interface

The block diagram in Figure D1 shows the operation of the output interface. The word to be written on tape is assembled in the computer accumulator. Then one of the write commands is given from the computer. This loads the data into the buffer so that it is available to the tape heads when the actual write command is generated. After a suitable settling delay, the actual step-and-write command is generated. This steps the tape one increment (1/200 inch) and writes the data from the buffer on the tape. After a delay to allow the stepping and writing to be executed, the interface signals the computer, via the write-status flag, that another character can now be written.

If it is desired to write a series of characters in synchronous mode (500 characters per second) the first write command must be "start synchronous write". This sends several step commands to the motor to get it up to speed. Then it sends one step-and-write command to write the first character. It is then necessary for the computer to send "write synchronous" commands every 2 milliseconds until an end-of-record signal is sent.

When writing in asynchronous mode (200 or fewer characters per second) it is simply necessary to generate a "write asynchronous" command every 5 or more milliseconds.

The "write EOR" and "write EOF" commands cause end-of-record (EOR) and end-of-file (EOF) gaps respectively to be written on tape. These are compatible with the computer industry standards.

The EOR/EOF flag signals when an EOR gap, an EOF gap, or a load gap has been completed. That is, it signals when the recorder is ready to start another write series.

The end-of-tape and tape-break signals are generated in the tape recorder when the appropriate condition exists.

Figure D2 shows the schematic for this interface and Table D1 shows the components and costs. The interface was constructed using Digital Equipment of Canada modules and hardware. The column headed "Part No." lists DEC part numbers for these items.

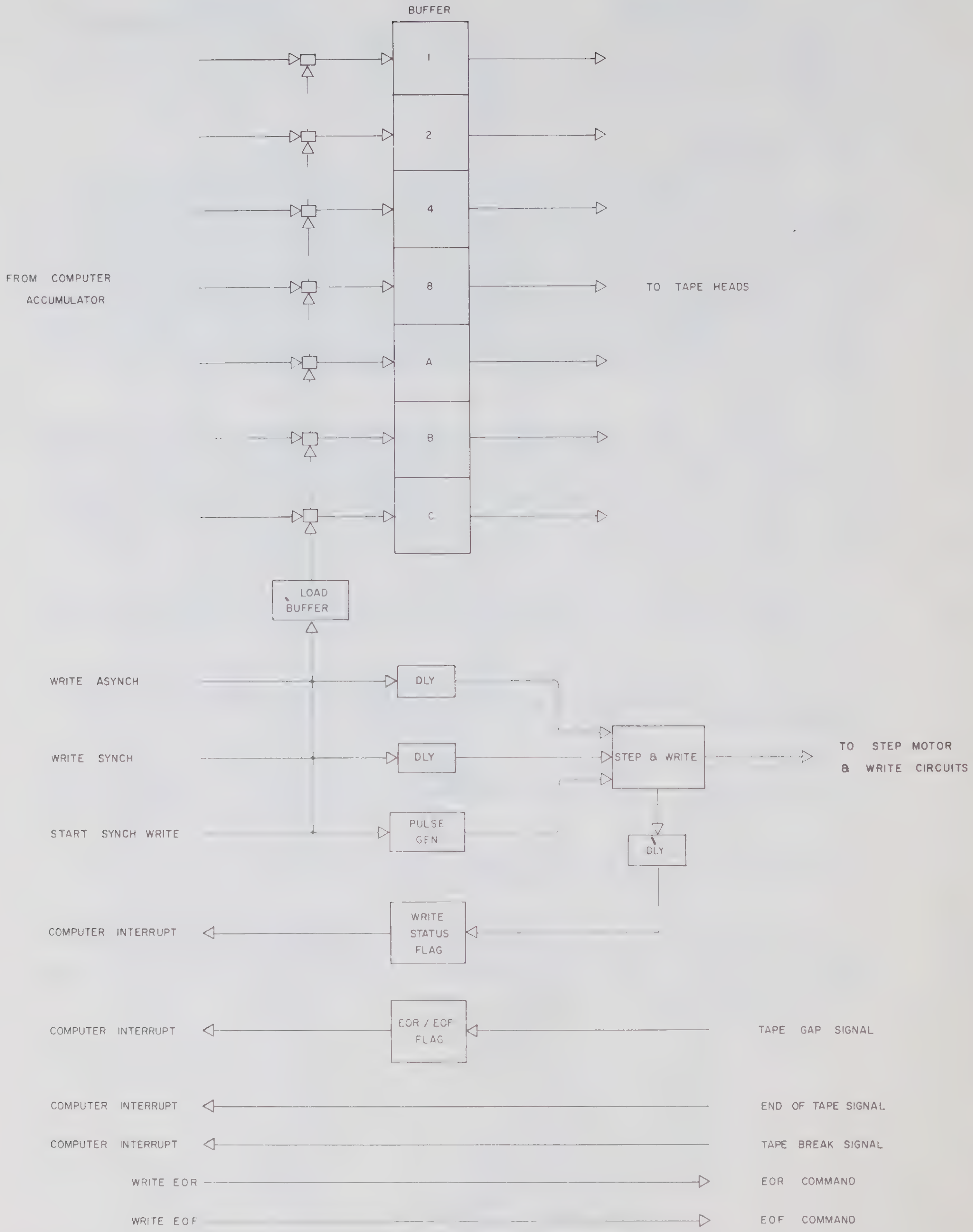


Figure D1. Output Interface Block Diagram.

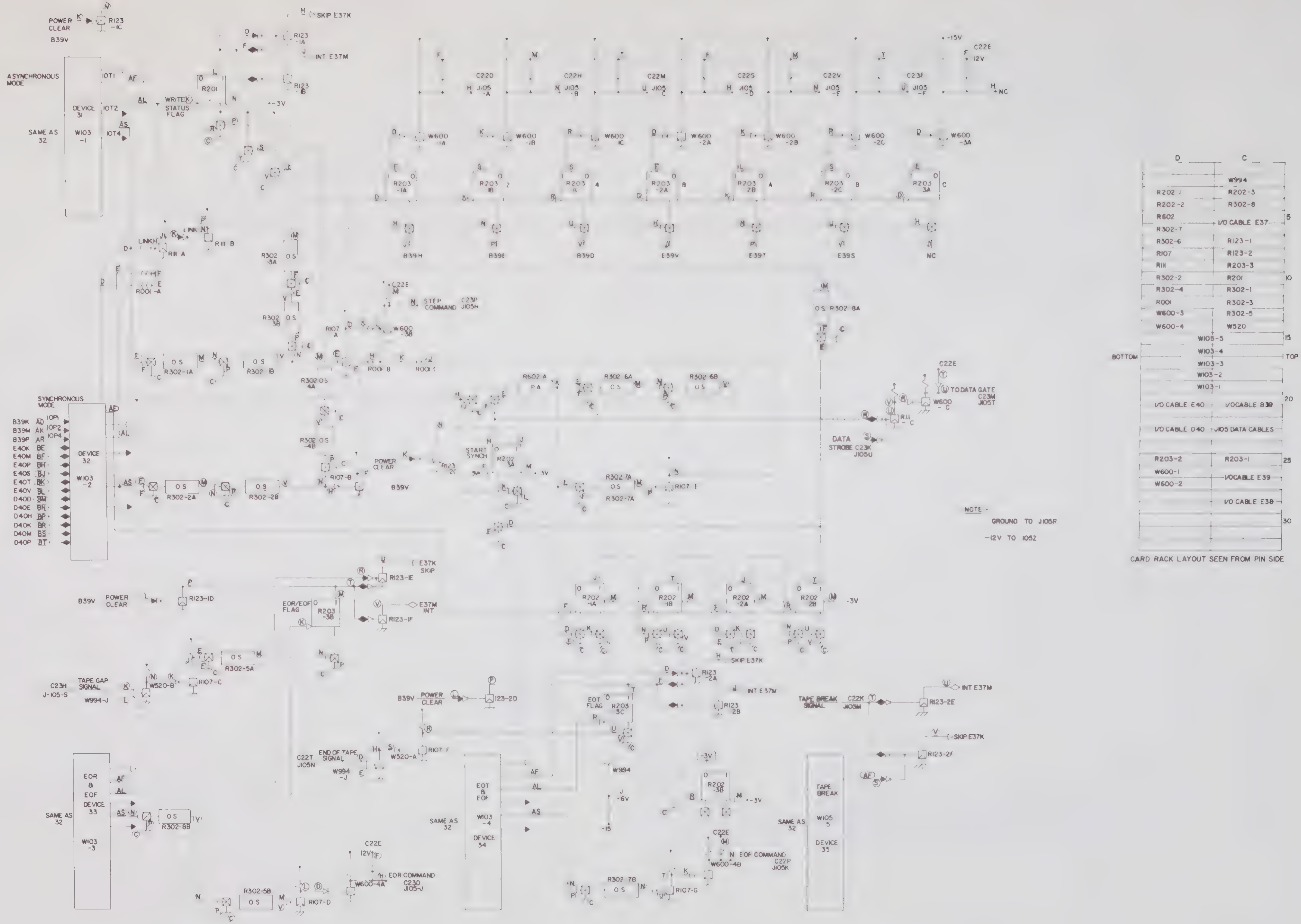


Figure D2. CCIW Data Translator - Incremental 7-track Tape Recorder Interface.

TABLE D1

Output Interface Components

Part No.	Qty.	Unit Pr. $ U.S.	Total Price $ U.S.
R001	1	4.00	4.00
R107	1	24.00	24.00
R111	1	14.00	14.00
R123	2	19.00	38.00
R201	1	22.00	22.00
R202	3	25.00	75.00
R203	3	28.00	84.00
R302	8	44.00	352.00
R602	1	22.00	22.00
W103	5	52.00	260.00
W520	1	43.00	43.00
W600	4	12.00	48.00
W028 Cables W028	6 6 ft., 2 conn.	29.60	177.60
W028 Cable	1 6 ft., 1 conn.	16.60	33.20
64 Card Rack 1943	1	121.00	121.00
Total Price $ U.S.			1317.80
+ 10%			131.78
Approximate Total Canadian Price			$1449.58

System Costs

PDP-8/S Computer with teletype and 4K memory	$10795.00
PI 1167 Write-Only Incremental Tape Deck (7-track)	3942.00
2 Cabinets @ 756.00	1512.00
HP 1205A/R Oscilloscope	984.00
Sony TC-104 Tape Recorder	180.00
Input Interface (from table C1)	1357.00
Output Interface (from table D1)	1450.00
Power Supply, Type 728	264.00
Total System Cost ($ Canadian)	$20484.00